High-Brightness Electron Source Laboratory (HBESL) in Fermilab's A0 building

An Expression of Interest for the formation of a Collaborative Laboratory for Beam and Laser Physics Research toward the Generation, Acceleration and Manipulation of Bright Beams

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13 October 2009

~~NIU@FNAL~~ Source Development Laboratory

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US CONGRESSMAN
BILL FOSTER
Representing the 14th District of Illinois

FY11 request for appropriation

Project: Particle Source Development Laboratory
Requested Amount: $3,000,000
Requested By: Northern Illinois University, 300 Altgeld Hall, DeKalb, IL 60115
Description: The funding would be used for the formation and operation of a Particle Source Development Laboratory in collaboration with Fermi National Accelerator Laboratory (Fermilab).
Benefit to Taxpayers: A Particle Source Development Laboratory, a collaborative effort between Northern Illinois University and Fermi National Accelerator Laboratory, will allow for accelerator science research in the development and study of novel high brightness electron, proton, and ion beams; the study of high intensity beam dynamics; and the development of beam diagnostics.This capacity will have a profound influence on science, technology, and the global economy, including the use of accelerators in fields as diverse as nanotechnology, medicine, food processing, and national security. Over 10,000 accelerators are now in operation around the world, and the demand is expected to grow. As the applications of accelerators increase, so will the need for trained graduate students, undergraduates, and operators and technicians.
Jobs: This program will offer new high-technology, high paying career opportunities for graduates in industry, defense, energy and environment, medicine, and discovery sciences.

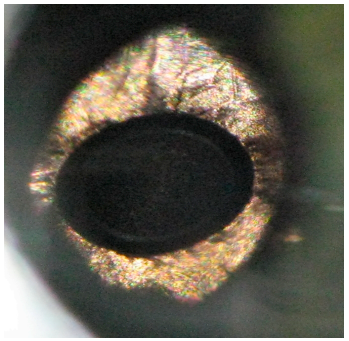
Motivations & Needs: University perspective

- University groups are well suited to explore cross-disciplinary aspects of Accelerator Science and engage in high-risk high-payoff R&D activities,
- Accelerator Science has multidisciplinary applications (high-energy physics, basic energy sciences, medicine, …) and development from one field of applications may be beneficial to another one (e.g. there is a strong synergy between FEL and HEP accelerators),
- National laboratories have limited support for accelerator science R&D and have to narrow the R&D to focus on their mission.
- Granting to Chicago area universities access to an accelerator infrastructure such as the A0 vaults would foster a great amount of independent research that could benefit to Fermilab (e.g. through education of accelerator scientist and technical achievements).

Synergy with FNAL (1)

- The proposed HBESL facility would provide an offline facility to test, develop, and commission next generation rf guns for NML

- NML will heavily depend on the performance of its rf-gun (that is the first 0.25 m of the 140-m-long accelerator!):
  - Beam Dynamics: rf guns set initial conditions and ultimate brightness; R&D toward new rf gun, cathodes, and laser systems could help improving NML beam brightness.
  - Operation/reliablity: rf guns have limited lifetime, that could seriously impact the operation of a SCRF linac (e.g., dark current leads to heavy, non-compensable, beam loading)
- An offline rf gun test stand would be beneficial to, e.g., prepare guns and study damaged guns



Cathode area of A0 rf gun, Courtesy H. Edwards (2008)

- Facilities requiring high reliability generally operate source/injector test stands, e.g., APS (ITS), DESY/FLASH (PITZ), SLAC/LCLS (GTF & X-band TS)

Synergy with FNAL (2)

- Besides supporting the NML effort, the other researches proposed at HBESL are within the mission of the APC and AD.

Accelerator Division Mission Statement

Roger Dixon, Head

- Provide the expertise to deliver reliably and cost effectively particle beams to qualified researchers conducting basic research at the frontiers of high-energy physics and related disciplines.

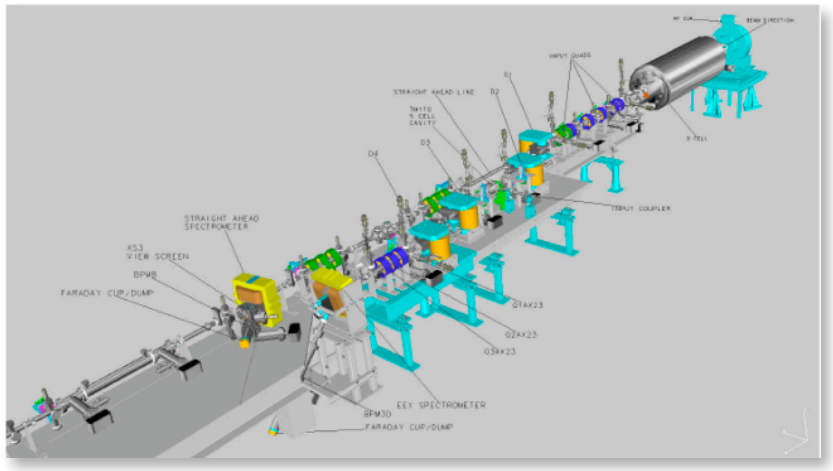
- Operate, maintain and improve the existing Fermilab accelerator complex and beam lines.
- Conduct particle beam physics research.
- Develop, design and build the accelerators and subsystems required to advance the field.

APC Mission Statement

- Coordinate and conduct accelerator R&D aimed at next-generation and beyond accelerator facilities
- Provide accelerator physics support for existing operational programs and the evolution thereof
- Train accelerator scientists and engineers
- Provide leadership and coordination in establishing the necessary experimental programs for a broad range of accelerator R&D that can be accessed by both Fermilab staff and the world HEP community.

A0 current status and plans

- Fermilab's A0 photoinjector has provided beam to support key accelerator physics experiments in (see Y.-E Sun's talk)
  - Beam dynamics: electro-optical imaging, asymmetric-emittance beams, transverse-to-longitudinal emittance exchange,
  - Advanced accelerator concepts: plasma wakefield acceleration, plasma lens in under-dense regime.



- NIU is actively involved in A0: NICADD partially supported A0 operation from 2002 to 2005 and NIU has 3 experiments running (or in preparation) at A0 and one student in the FNAL PhD program.
- The current plan is to decommission the photoinjector and reuse some of the components for the NML injector,
- The hardware remaining in the A0 vault could, *with minor efforts*, be configured as a 1.3 GHz electron source with small beamline.

A0 decommissioning plans

- A0 will stop operation in the Fall 2011 consistent with producing first beam at NML in 2012.

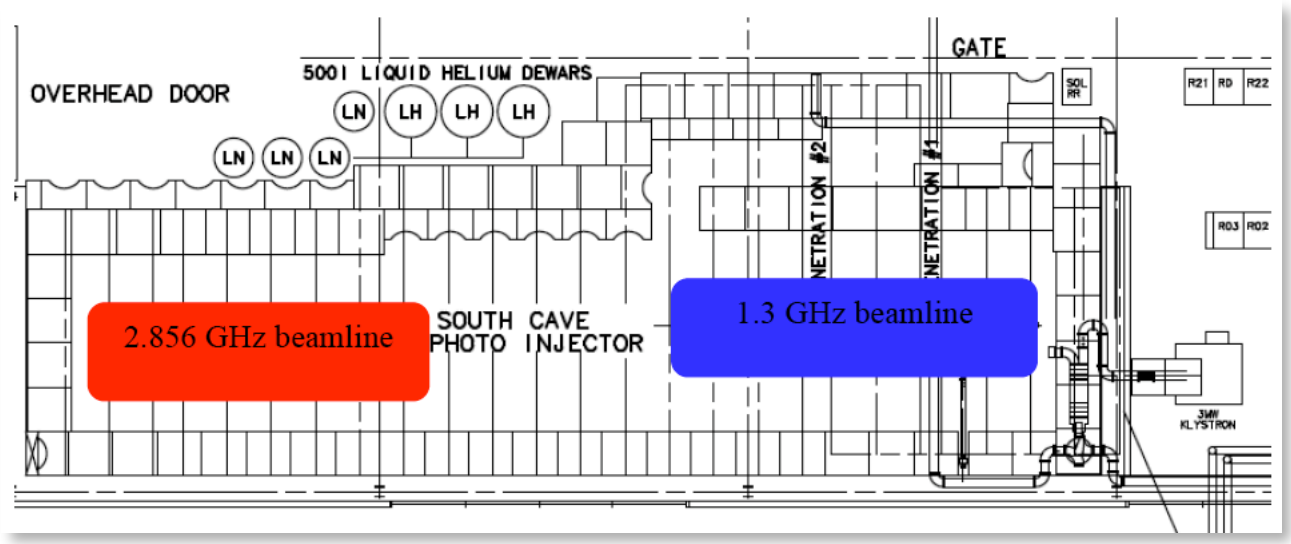
- The main components to be relocated to NML are
  - SCRF cavity,
  - Vacuum components, diagnostics cross,
  - Part of the photocathode drive-laser transport line.

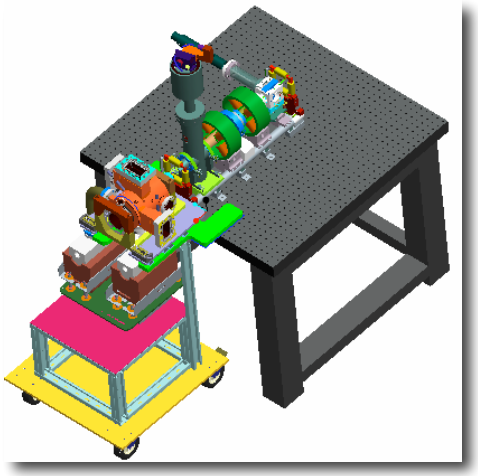
- A0 building will still have
  - Infrastructure (radiation-shielded vault, temperature-stabilized laser room, control room with minor lab space)
  - 3 MW + 200 kW 1.3 GHz klystrons with associated modulator & control etc..
  - A 1.3 GHz 1+1/2 rf gun
  - Two drive laser systems [a 3-ps uv laser and a 50 fs Ti:Sp (from NIU)]
  - Vacuum components (diagnostics, ions pumps) & associated controls

A0 as a source development Lab (1)

- The vaults would incorporate two beamlines: both beamlines would initially provide low energies (~5 MeV) electron beams.

S-band beamline: pursue high-risk university-driven R&D (e.g. novel cathodes (FEA), bunch shaping, multifrequency guns,…)



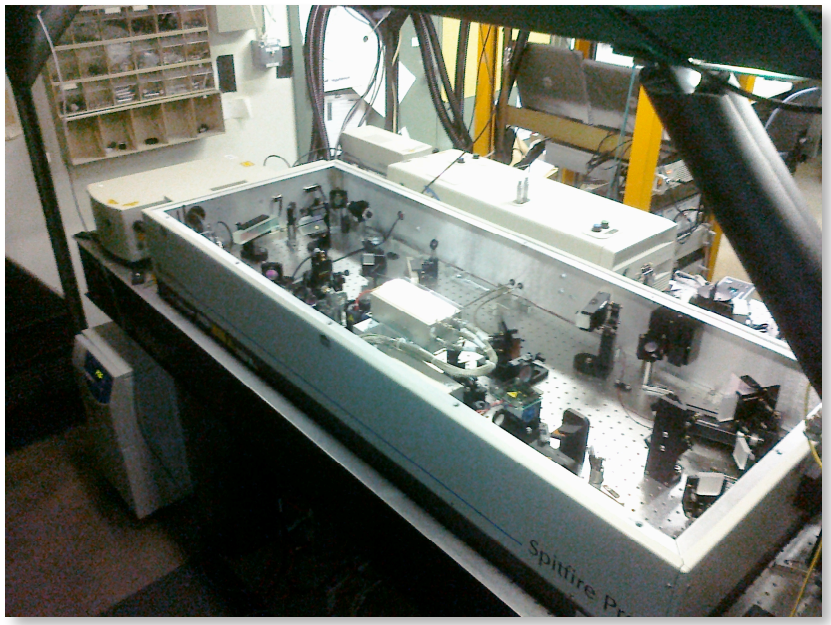


S-band facility, Courtesy from ME dept NIU

L-band beamline: perform R&D in support to the NML facility (new 1.3 GHz gun geometry, higher E-field guns, bunch shaping, cathode studies)

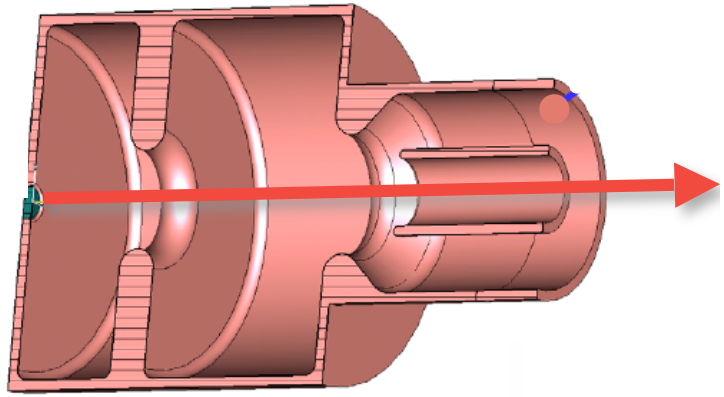
A0 as a source development Lab (2)

- NIU already has a laser system capable of driving both a 1.3 GHz and 2.856 GHz beamline (part of it at A0).



- The 1.3 GHz gun will most probably be replaced with a new generation gun [FNAL currently has 3 coaxial rf guns (DESY design)].

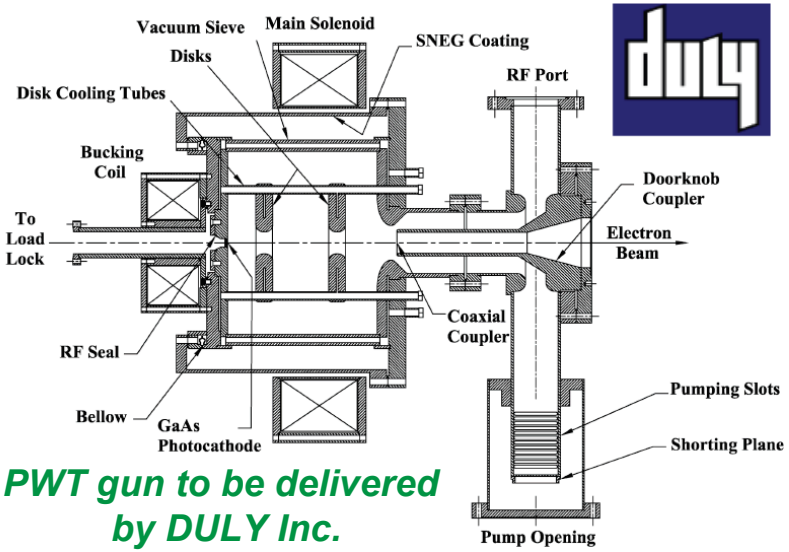
- Most of the 2.856 GHz beamline is in hands (6 MW klystron, modulator, circulators, waveguides, vacuum components)



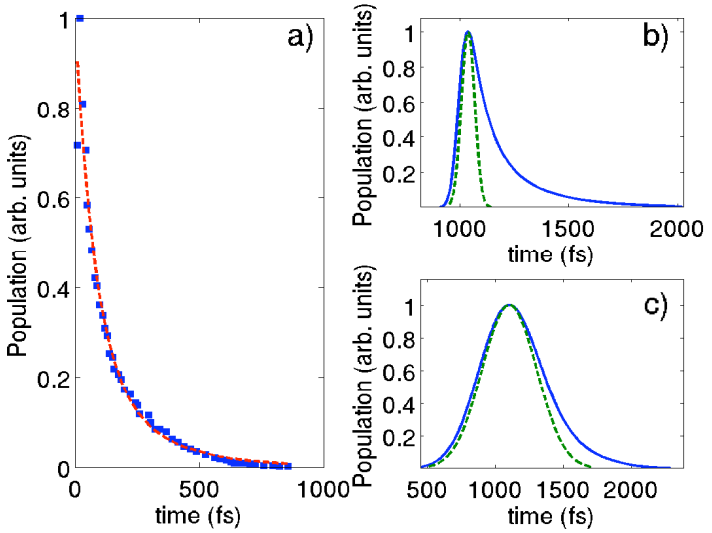
- Only the S-band rf-gun is missing (*we has discussion with ANL/APS spare S-band gun as a starting point, formal request still needed*)

Example of R&D on L-band beamline

- Gun study and new developments
  - Plane wave transformer (PWT) gun operating at 1.3 GHz (SBIR phase 2 with DULY Inc. funded),
  - Exploration of field emission in guns
  - Alteration of DESY gun designs to improve performances,
- Exploration of cathodes properties
  - First measurement of response time of Cs_2Te photocathode,
- Pulse shaping
  - Spatio-temporally-shaped laser pulses to produce tailored 3D beam distribution,
- Diagnostics/control
  - Dark current collimation, low energy diag.
- Gun preparation for NML
  - Rf conditioning, performance evaluation.



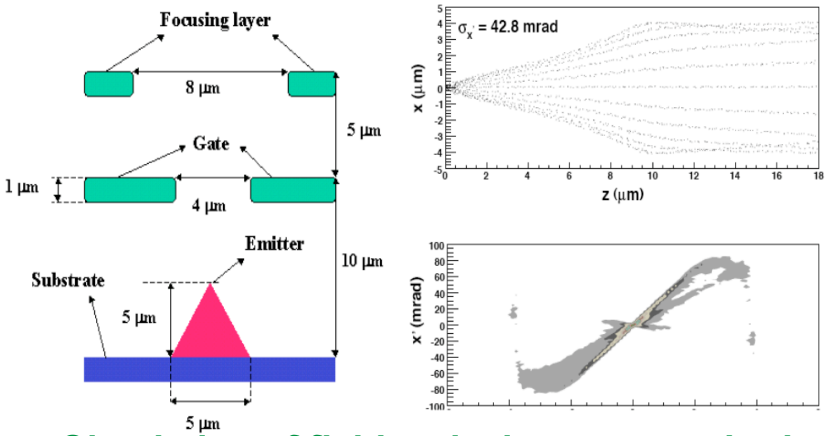
PWT gun to be delivered by DULY Inc.



Simulated response time of Cs_2Te

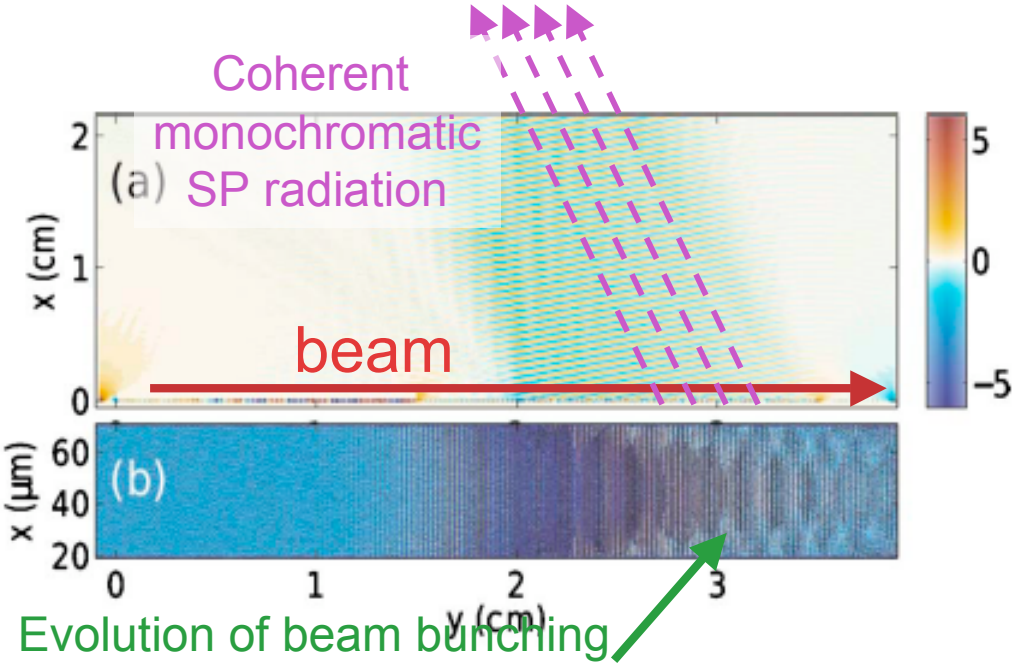
Example of R&D on S-band beamline

- Exploration of novel cathodes
  - Investigate the operation of field emission arrays in an rf gun.



Simulation of field emission array cathodes [Mihalcea, Piot, LINAC08 (2008)]

- Compact radiation source



Simulation of a low-energy Smith-Purcell FEL [Prokop , Piot et al., APL (2010)]

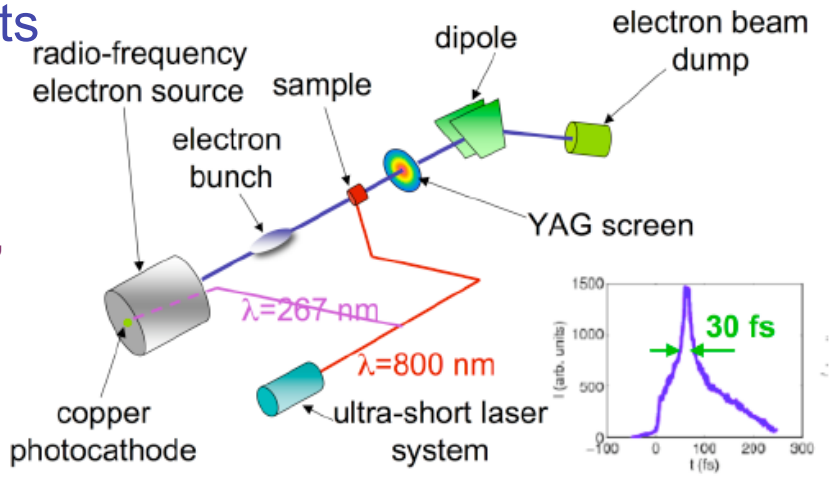
- 3D beam shaping to enhance beam brightness or tailor the beam shape
  - Laser shaping,
  - Phase space manipulations,
  - Multifrequency rf-guns (2.856 GHz + harmonics
- Support for construction/test of accelerator components for an MIT proposal (NIU is subcontractor)

R&D beyond Accelerator Research

- Education of future accelerator physicists
  - NIU beam physics curriculum,
  - NIU master in rf engineering,
  - College of Dupage accelerator program,
  - Could also be used for future USPAS.

- Beam for user-driven applications
  - Radiolysis with low energies short pulses beams,
  - Ultrafast electron diffraction using relativistic beams [S-band line could provide ~30 fs (FWHM) 100-pC electron bunches],
  - Engineering issues for water treatment facility with electron beams.

- Laser research and applications to accelerators



Setup for ultrafast electron diffraction [Piot, Gaillard, Demir, 2009]

http://www.symmetrymagazine.org/cms/?pid=1000753

NIU contributions

- one staff member to serve as lead scientist and facility research director and coordinator;
- upgrade components and installation costs, as incurred, for NIU-sponsored experiments;
- staff time and presence as required to conduct experiments in the facility
  - Graduate and undergraduate students,
  - Research associated,
  - and Faculties (Physics, EE, and possibly Chemistry/biochemistry);
- $30k/year for the maintenance of the laboratory through grant matching funds (still need to be “re-”negotiated)

Support needed from FNAL

- In kind contribution (approximately $100k/year) for
  - the maintenance of the laboratory (e.g. electrical/water consumptions, compressed air, etc…),
  - and safety oversight, (interlock tests, operational procedure review, etc…);

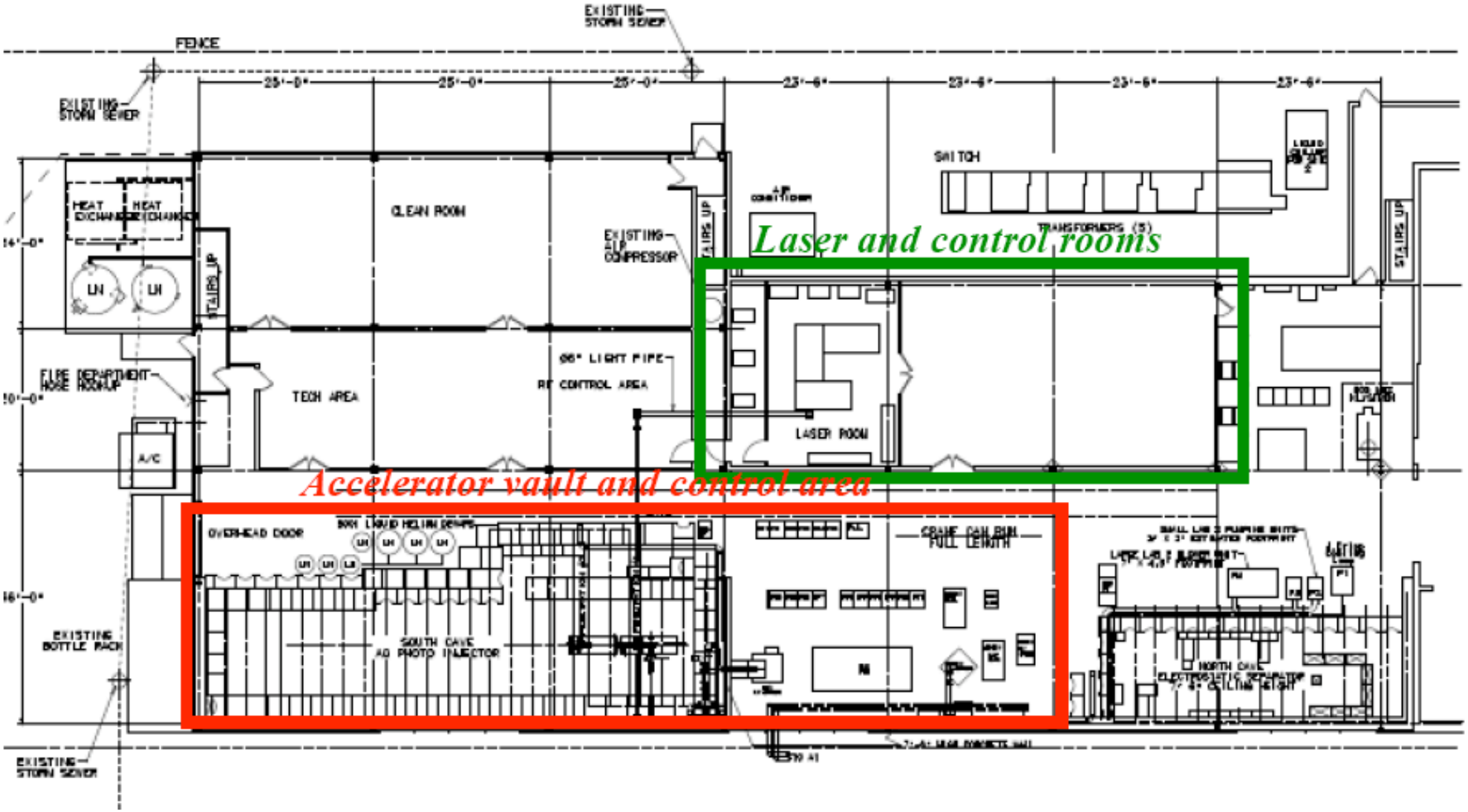
- assistance (on a time-as-available basis) with components, beamline and facility upgrade
  - estimated to be 0.25 technician (FTE);

- upgrade components, installation, and operations costs for Fermilab-sponsored experiments

- Recognized SDL users as “visitors” and provide necessary trainings.

Space request in the A0 building

- SDL would require only half of the A0 building area (the vault and control area and the laser and control rooms)



Summary

- Upon decommissioning of the A0 photoinjector, the A0 building would still have the infrastructure needed to continue supporting a rich research program on high-brightness electron sources,
- We propose to use the infrastructure to setup a high-brightness electron source development lab to be operated/managed in partnership between NIU and the APC,
- FNAL, with modest investments, would have access to a facility that would support NML, e.g., for guns development/conditioning,
- Chicago area universities would have access to a competitive infrastructure and would leverage on it to attract extramural funding,

- The facility would be available to other group on a pay-to-play basis,
- The facility would also provide a state-of-the-art training platform for students at local universities, colleges, and Fermilab,
- Other Chicago area universities and College (e.g. UChi, IIT, COD), have expressed their interest in joining this Lab.